Quantifying, Predicting, and Exploiting (QPE) Uncertainty

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LONG TERM GOALS

The long term goal of our QPE work is to: 1) quantitatively understand what the uncertainties are in low frequency (10-1000 Hz) acoustic propagation and noise that are caused by variable and complex oceanography and seabed structure, 2) determine the limits to predicting the fluctuating and variable propagation and noise in this frequency regime and others, and 3) ascertain what naval advantage may be gained (if any) by understanding the nature of the uncertainty.

OBJECTIVES

Our primary objectives this year were: 1) to analyze the data from the 2008 pilot experiment, and 2) to participate in the main experiment in the East China Sea in 2009.

APPROACH

Planning for the 2009 main experiment was accomplished via examining the pilot experiment data, running computer simulations of propagation at the experimental site, and holding a series of meetings at MIT, WHOI, and other venues. Using the meeting results as guidance, the main experiment to the northeast of northern Taiwan was successfully carried out in August-September, 2009.

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14. ABSTRACT
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WORK COMPLETED/ACCOMPLISHMENTS

Our main accomplishment this year was the final planning for and successful completion of the shallow water field component of the QPE project. This was done by performing preliminary computer simulations and then executing a ten-day long initialization cruise whose data was input to ocean/acoustic computer modeling/prediction codes. The model prediction outputs were then used to guide a second cruise immediately following that tried to optimize acoustic transmissions at both a shelf and a shelfbreak site.

RESULTS

During the QPE main experiment, we made 14 separate mooring deployments and recoveries, all of which gave us usable data, and in some cases extraordinarily good data. We had a maximum of four environmental monitoring moorings at each deployment site, and the temperature data from the sensors on one of these moorings is shown in

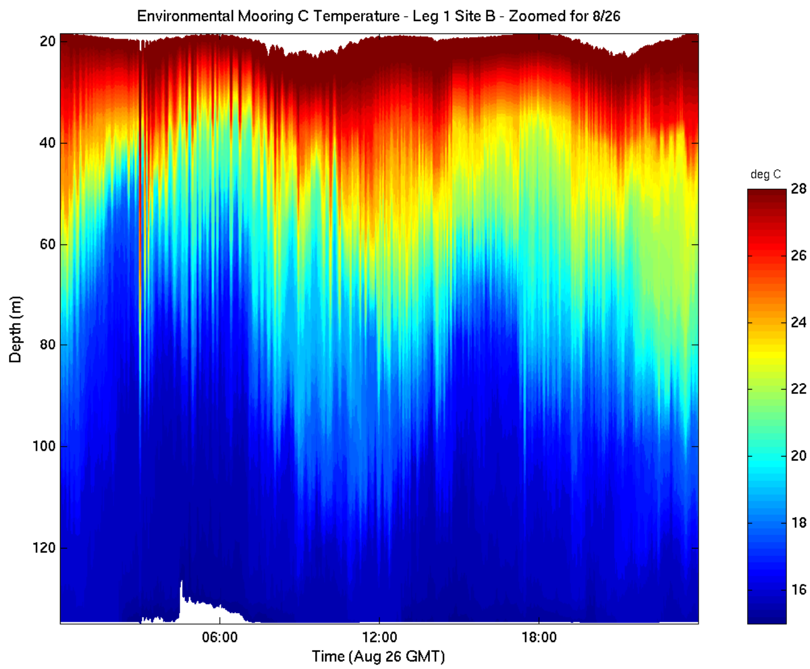


Figure 1. Section of thermistor string data from mooring at shelfbreak site B during leg 1 of the QPE main experiment. Very strong internal tides and internal waves are noted. One day of time is shown.

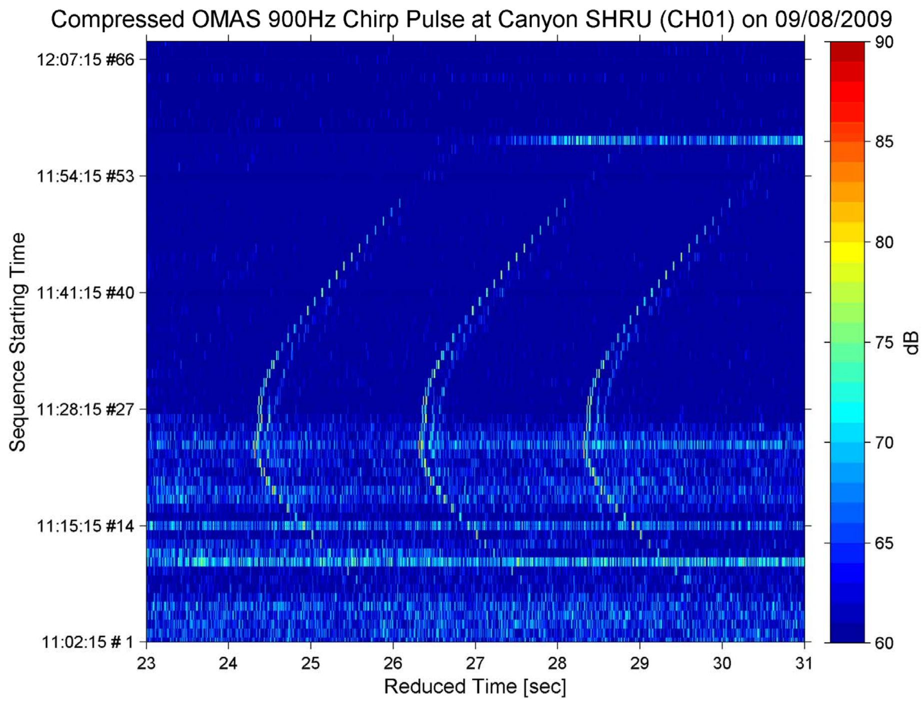


Figure 2. Compressed chirp pulse (900 Hz center frequency) arrival times at SHRU receiver showing clear multipath arrivals, the point of closest approach, and fading as source transits over a canyon feature.

Figure 1. The very strong internal tides and internal waves are prominent, and should be large influences on acoustic propagation and noise at the experimental site. Also deployed were two SHRU (several hydrophone receiver units) four-element vertical receiver arrays per deployment site, which gave a stationary moored counterpart to OASIS, Inc. drifting sonobuoys that were used in the area, as well as spatial diversity. Output from one of these receivers is shown in Figure 2. Also deployed was an eight-element Webb horizontal array in a bottom lying configuration. This array was deployed to look at azimuthally directional noise, as well as the transmissions from the OMAS sources. Data from the Webb array (a single phone) is shown in Figure 3. The sweeps and CW tones the OMAS transmitted are clearly seen in the sonogram record.

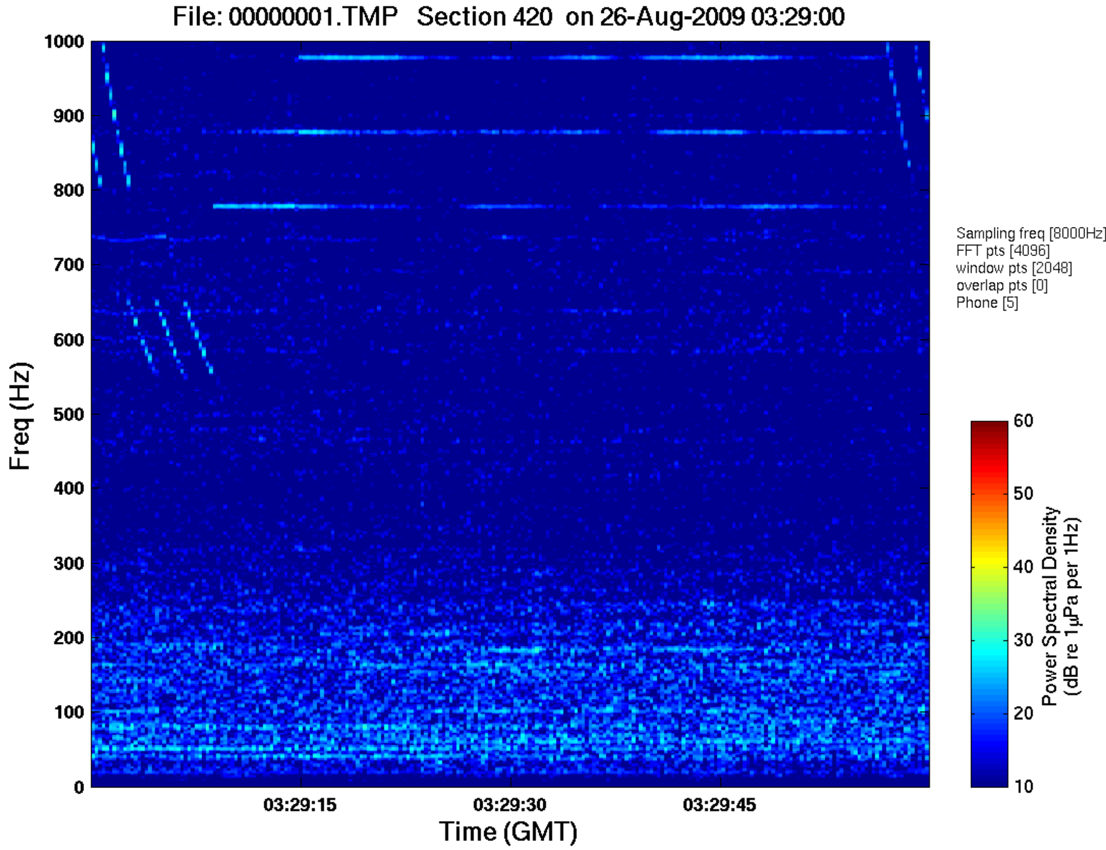
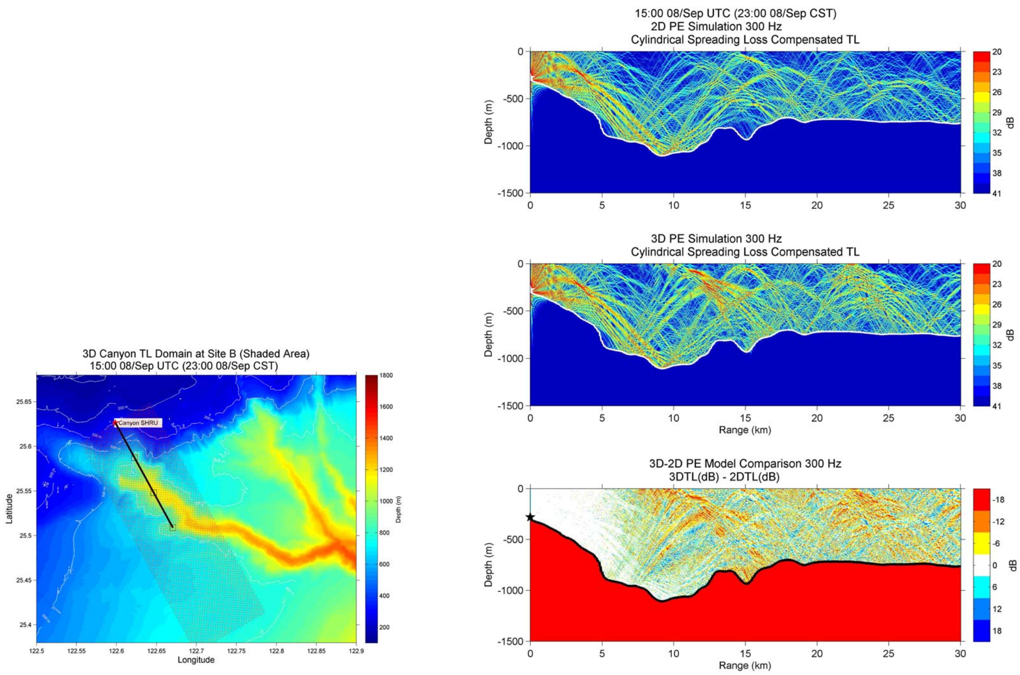


Figure 3. Output from a single hydrophone of the Webb eight-element horizontal line array deployed in QPE. The OMAS CW and chirp transmissions are clearly seen, along with the noise spectrum.

Prior to the experiment, 3-D TL forecasts for predicting 3-D canyon acoustic effect son sound propagation were made, see Figure 4 for an example. This prediction was made by an acoustic propagation program that employs the split-step Fourier (SSF) technique to solve the 3-D parabolic acoustic wave equation (PE) for one-way propagating waves in a Cartesian coordinate system. In addition to the 3-D canyon TL forecasts, we also implemented normal mode calculations for predicting the acoustic modal variability due to water-column condition changes, see Figure 5 for an example.



(a) (b)

Figure 4. 3-D canyon TL calculation. Panel (a) shows the calculation domain, which is the west branch of the North Mien-Hua Canyon. Panel (b) is a comparison of the TL predictions from 2-D and 3-D theories.

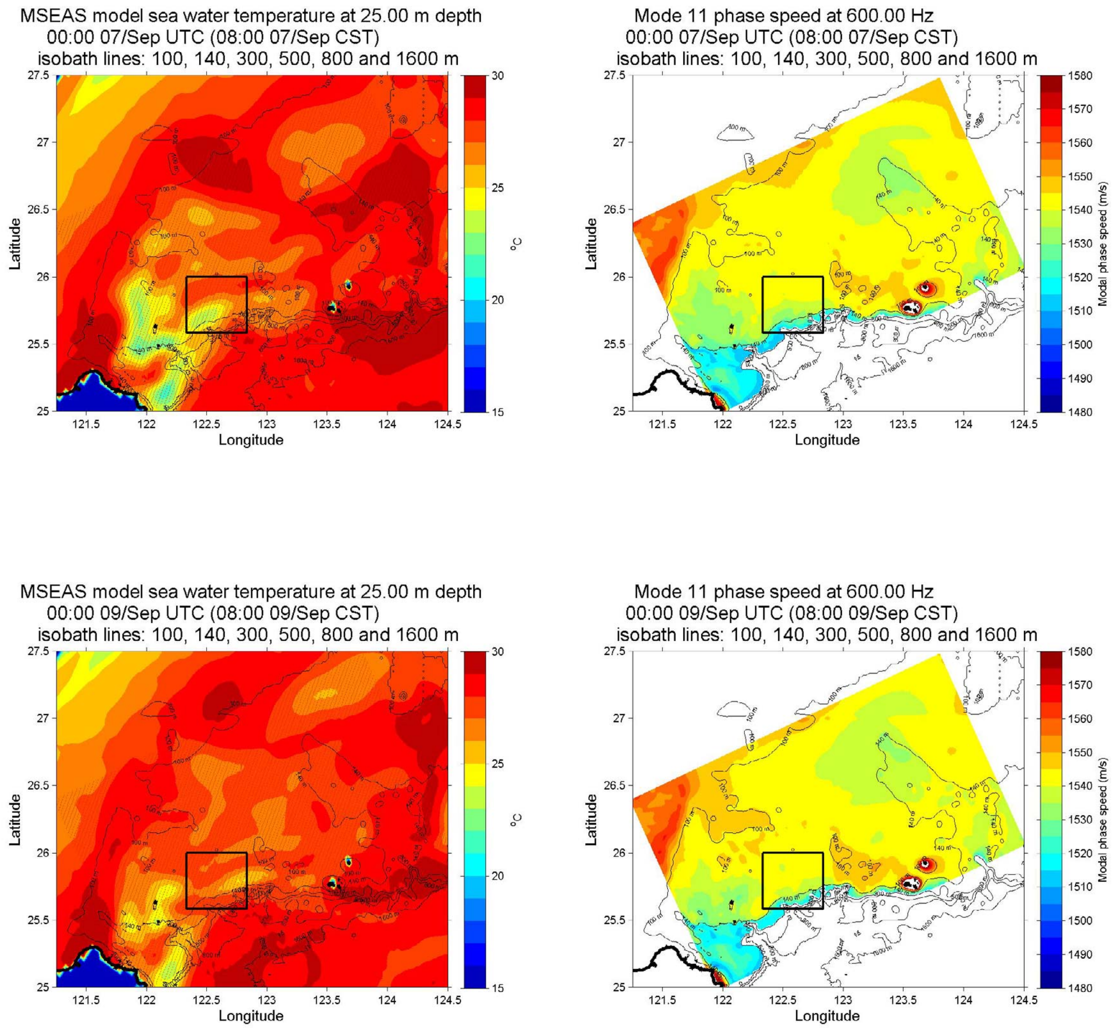


Figure 5. Acoustic normal mode variability for 07 Sep 00:00 (GMT) and 09 Sep 00:00 (GMT). The water temperature at 25.0 m depth predicted by the MIT Multidisciplinary Simulation, Estimation, and Assimilation System (MSEAS) is shown in the left panels for these two periods, and the right panels are the phase speed maps of mode 11. Boxes indicate the acoustic survey area.

IMPACT/APPLICATIONS

The impacts of our work so far are that we have a good data set to work with, and a set of predictions (and decisions made on their basis) that we can use to determine how well our Prediction, Quantification, and Exploitation of Uncertainty really was. This is a prototype of a real application.

TRANSITIONS

One eventual transition of our work will be to naval sonar systems and to sonar analysis, where the interest is in “the error bars” in ocean acoustic field and system performance prediction.

RELATED PROJECTS

The SW06 experiment also had an Uncertainty-related component, only in a different geographical area. OASIS Inc. QPE component. Numerous physical oceanographic QPE field studies. MIT data-driven modeling of the work area.